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... think scientifically, act scientifically... think scientifically, act scientifically... think scientifically, act...

EDITORIAL

Bringing science from lab to the masses

Chander Mohan

One of the major objectives of Department of Science and Technology (DST) is to stimulate scientific temperament and popularise as well as communicate Science & Technology (S&T) to masses through several programs and schemes. DST primarily fulfils this mandate through two of its apex agencies - National Council for Science and Technology Communication (NCSTC) and Vigyan Prasar. Despite a plethora of initiatives undertaken by DST, it was felt that there existed a wide gap in delivering outcomes of scientific research in a language and manner which even a person with non S&T background could understand. To address this chasm in public understanding of science in India, for the first time, these two agencies joined hands to strengthen the ecosystem for Science Communication in the country. The initiative aims to encourage, empower and endow popular science writing through newspapers, magazines, blogs and social media and thus has been aptly named as Augmenting Writing Skills for Articulating Research (AWSAR). AWSAR has been conceived to encourage research scholars to (a) submit at least one story/ article based on their research work; (b) foster, strengthen and create a culture of science communication/popularisation among them; and (c) recognise their initiative and output on the myriad subjects under the realm of S&T.

AWSAR would be implemented by VP in consultation with NCSTC and it envisages organisation of 3-4 workshops every year for capacity building and handholding in order to make young researchers conversant with the art of writing popular science articles. These workshops would involve luminaries in the field of popular science writing from media, publishing houses and celebrated scientists involved in the activity.

The stories would primarily be invited through various media and target scholars pursuing PhD and Post-Doctoral Fellows (PDFs) in various streams of S&T. A panel of experts comprising of science communicators, scientists and technologists would analyse these stories. AWSAR entails monetary incentive of Rs.10,000 each for 100 best entries from PhD scholars in a year along with a Certificate of Appreciation besides getting the story published/projected in mass media. In addition, three leading stories from the selected 100 would also be awarded cash prize of Rs.1,00,000, Rs.50,000 and Rs.25,000 respectively. Further, 20 entries would be selected from articles submitted by PDFs relating to their area of research for monetary incentive of Rs.10,000 each and one outstanding story to get a cash prize of Rs.1,00,000.

This unique program will bring information about research being carried in the lab in interesting format(s) to the masses thus bridging the yawning gap that currently exists and also create new opportunities in the area of science journalism for our researchers. So, dear researchers in S&T domain, the advertisement inviting entries is being released in leading newspapers and will also be placed on the websites of DST, VP and allied agencies. Come and join the new wave and do your bit to strengthen the scientific temperament amongst our countrymen.

Jai Hind!

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Ejnar Hertzsprung

Discoverer of the Stellar Type-Luminosity Relationship

Subodh Mahanti

Ejnar Hertzsprung, who had no formal education in astronomy, became one of the important astronomers of the twentieth century. He came up with the idea of 'absolute brightness' by observing the fact that a nearby dim star can appear to be brighter than a faraway bright star. He was little perplexed by this apparent anomaly. To overcome this apparent anomaly he proposed the concept of 'absolute magnitude' or the intrinsic luminosity of a star and not its apparent brightness.

"Hertzsprung was the first to realise that there was a relationship between the spectral colour of stars (As defined and classified by Antonia Maury) and their luminosity…"
— *The Cambridge Dictionary of Scientists (2003)*

"One other major achievement of Hertzsprung was the development of a method for the determination of stellar and galactic distances."
— *A Dictionary of Scientists, Oxford University Press (1999)*

"In 1905 he (Hertzsprung) showed how a star's luminosity was related to the width of lines in its spectrum, thus establishing spectroscopic parallax as a means of distance-finding. He inferred the distinction between red giant and dwarf stars…Hertzsprung also proposed the modern definition of absolute magnitude. He went on to plot the first Hertzsprung-Russell diagram, for the stars of the Pleiades, in 1906."
— *A Dictionary of Astronomy, Oxford University Press (1997)*

Ejnar Hertzsprung, who had no formal education in astronomy, became one of the important astronomers of the twentieth century. He is mostly known for the graph called Hertzsprung-Russell diagram or simply H-R diagram. The diagram or the graph is regarded as one of the most useful and powerful plots in astrophysics. It is a graph on which a measure of the brightness of stars, usually their absolute magnitude, is plotted against a measure of their temperature, either spectral type or colour index. The Hertzsprung-Russell diagram acted as a basis for the study of stellar evolution. In fact, it became the starting point for discussions on stellar evolution.

Ejnar Hertzsprung

The Hertzsprung-Russell diagram originally indicated two main types of stars namely dwarfs or the Main Sequence stars (like our own star, Sun, which a yellow dwarf) and giants (some hundred times larger), which were later followed by the discovery of planet-sized white dwarfs and huge super giants. Hertzsprung and Henry Norris Russell (1877-1957), an American astronomer, independently plotted logarithmic graphs of stellar luminosity against surface temperature. The diagram shows how the luminosities and their temperatures of stars are related. The area of the Hertzsprung-Russell diagram between the top end of the main sequence, containing the numerous faint dwarfs and the giant branch, containing more luminous but fewer in number giant stars is called the Hertzsprung gap. It contains no stars.

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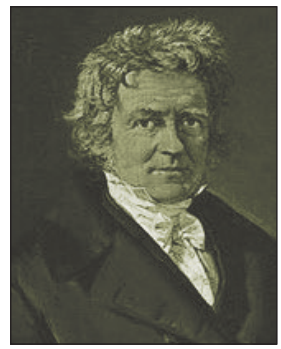
Hertzsprung came up with the idea of 'absolute brightness' by observing the fact that a nearby dim star can appear to be brighter than a faraway bright star. He was little perplexed by this apparent anomaly. To overcome this apparent anomaly he proposed the concept of 'absolute magnitude' or the intrinsic luminosity of a star and not its apparent brightness. The brightness of a star usually perceived by an observer is its apparent brightness. For comparing the brightness of stars he proposed a system in which he imagined all the stars were at the same distance from the observer, a distance of 10 parsecs (parsec is a basic unit of stellar distance, corresponding to a trigonometric parallax of one second of arc).


Henry Norris Russell

Hertzsprung measured the proper motions of stars—their angular motions in a direction perpendicular to the observer's line of sight. He used the results thus obtained to establish membership of clusters. He developed a method for the determination of stellar and galactic distances. Earlier, two German astronomers, namely Friedrich Wilhelm Bessel (1784-1846) and Friedrich Georg Wilhelm von Struve (1793-1864) used measurements of annual parallax to calculate stellar distances. However, their method was only accurate up to distances of about a hundred light years. Henrietta Swan Leavitt (1868-1928), an American astronomer, had demonstrated that the period of light variation of a group of stars known as Cepheid variables was linked to their mean brightness. Hertzsprung argued that Cepheids could be used to measure the distance of any group of stars having a Cepheid by observing the period and brightness of the Cepheid. He measured the distance to the Small (or Lesser) Magellanic Cloud, which is smaller than the present value, but it was the first measurement of an extragalactic distance. The Small Magellanic Cloud (SMC) is the smaller of the two irregular galaxies that accompany our Galaxy, the Milky Way. Also known as the Nubecula Minor, it is about 9,000 light years across and 190,000 light years away. The works of Hertzsprung and Leavitt led Harlow Shapley (1885-1972), an American astronomer, to figure out the proper shape of our Galaxy.

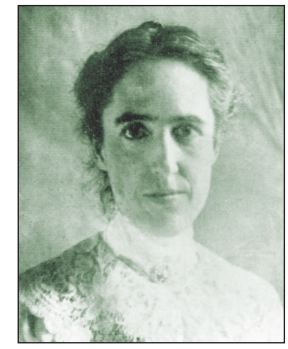

Friedrich Wilhelm Bessel

Hertzsprung produced a catalogue of mean colour equivalents of 734 stars in 1922. In this catalogue he discussed the relation between colour and luminosity of stars using proper motions as distances indicators for lack of reliable parallaxes. He also discovered two asteroids - 1627 Ivar (25 September 1929) and 1702 Kalahari (7 July 1924).

Ejnar Hertzsprung was born on 8 October 1873 in Frederiksberg near Copenhagen in Denmark. His father Severin Hertzsprung had a Master's degree in astronomy from the University of Copenhagen and he had received Gold Medal for his works in astronomy. However, as there were not much financial prospects in pursuing astronomy he joined the Department of Finances in the Danish Government and at a very early age he was appointed Director of the State Life Insurance Company. Hertzsprung's father had instilled a deep interest in astronomy and mathematics in his son's mind. However, he did not want his son to study astronomy or mathematics because he did not see much prospect in financial terms in pursuing a career in these subjects. He decided his son should get a more practical education. Hertzsprung took up the study of chemistry. He became interested in chemistry after reading a small book in chemistry by the famous Danish chemist Hans Peter Jorgen Julius Thomsen (1826-1909). Hertzsprung was 20 years old when his father died. It may be noted that his father's collection of books on astronomy were sold, as there was no one in the family interested in astronomy. After completing his school education in a Metropolitan School in Copenhagen, Hertzsprung obtained a degree in Chemical Engineering from the Polytechnical Institute in Copenhagen in 1898 and then proceeded to St. Petersburg (later renamed Leningrad and again restored to its original name), where he worked as a chemist. He studied photochemistry in Leipzig under the German chemist Friedrich Wilhelm Ostwald (1853-1932).

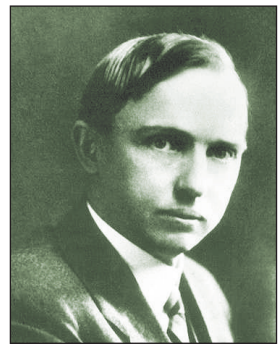

Friedrich Georg Wilhelm von Struve

After his mother's death Hertzsprung came back to Denmark in 1902 and lived on a small private income. He started working as an amateur astronomer at the Copenhagen University Observatory and the Urania Observatory in Frederiksberg. At the beginning of the 20th century when Hertzsprung started working in astronomy, the study of the physical nature of stars was still in its infancy. In the nineteenth century the focus on stellar astronomy was determining positions and motions of the stars. However, by the second half of the 19th century the Italian astronomer and priest Augeolo Secchi (1818-1878) and the English amateur astronomer and spectroscopist William Huggins (1824-1910) initiated their pioneering work in spectroscopy. Secchi, Warren de la Rue (1815-1889), a British astronomer and chemist, and the American astronomer William Cranch Bond (1789-1859) introduced the new technique of photography for studying stellar spectra. The Harvard College Observatory published three catalogues of photographically determined stellar spectra during 1890-1901. Hertzsprung started measuring star colours photographically. He was trained in photochemistry and so he was suited for making astronomical observations by using the technique of photography.


Henrietta Swan Leavitt

In 1905, Hertzsprung published his results in a paper titled "Zur Strahlung der Sterne" (Radiation of the Stars) in a journal devoted to photophysics and photochemistry titled

Zeitschrift fur Wissenschaftlische Photographia (Magazine for Scientific Photography). This was followed by another paper titled "Zur Bestimmung der Photographischen Sterngrossen" (Determination of the Photographic Star Sizes) in the same journal in 1907.

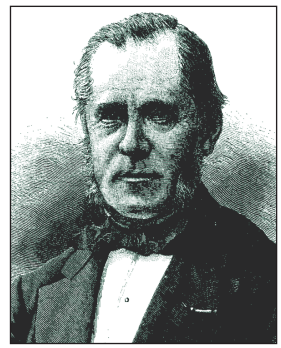


Harlow Shapley

Some of the conclusions drawn by Hertzsprung were:

- Stars in the spectral classes G K M can be grouped in two categories with different luminosity.
- The stars looking luminous red must be massive.
- There is a connection between the spectrum and the luminosity of stars.

The above papers did not include the diagram, which is now known as Hertzsprung-Russell diagram. This is because perhaps Hertzsprung did not think that he had sufficient data. In 1911 he published colour-magnitude diagrams of the Pleiades (a prominent open cluster in Taurus, popularly termed as Seven Sisters and it spans over 1.5° of the sky) and Hyades (a large, V-shaped open cluster in Taurus, spanning over 5° of the sky), the first diagram of this type ever to be published. It may be noted here that the existence of such a diagram remained mostly unknown until H N Russell presented such a diagram, independently developed by him, at a meeting of the of the Royal Astronomical Society in 1913. Russell was not aware of Hertzsprung's earlier work. Astronomers did not notice Hertzsprung's works as they were published in a journal of scientific photography and not in regular astronomy journals.



Hans Peter Jorgen Julius Thomsen

The first two papers published by Hertzsprung impressed Karl Schwarzschild (1873-1916), a leading German astronomer and then the Director of the Gottingen Observatory, so much that he invited Hertzsprung to visit the Gottingen Observatory in 1909 and within few months he was appointed as an Associate Professor. When Schwarzschild moved to Potsdam Astrophysical Observatory as its Director, Herzsprung also moved there where he was appointed as Senior Staff Astronomer. In fact, Schwarzschild had accepted the position on the condition that Hertzsprung would go with him. However, Hertzsprung's collaboration with Schwarzschild did not last long. In 1916 Schwarzschild died from a severe illness contracted during his military service at the eastern front in the First World War.

Friedrich Wilhelm Ostwald

Hertzsprung left Denmark in 1919 to take up the position of Associate Director of the University Observatory of Leiden, The Netherlands. He succeeded the Dutch mathematician and astronomer Willemde Sitter (1872-1934) to become the Director of the University Observatory of Leiden in 1935. Among his students at Leiden was the Dutch-American astronomer Gerard Peter Kuiper (1905-1973), who had first suggested the existence of the Kuiper Belt as the source of short-period comets. In 1944 after his retirement from the University of Leiden Hertzsprung returned Denmark and settled near the newly established University Observatory at Brofelde where he was actively engaged in astronomical research until 1966.

Hertzsprung was awarded the Gold Medal by the Royal Astronomical Society, London in 1929 for his determination of the distance of Small (or Lesser) Magellanic Cloud and other pioneering works in astronomy. The Gold Medal of the Royal Astronomical Society is its highest award. He received the Bruce Medal from Astronomical Society of the Pacific in 1973. He was awarded Ole Roemer Medal by the City of Copenhagen in 1929. He was member of more than 10 academies in Europe and USA.

Hertzsprung died on 21 October 1967 in Roskilde, Denmark. He was 94. His papers totalling 12,153 pages (with original manuscripts) were given to the US Naval Observatory Library where K.A.A. Strand, a former student of Hertzsprung, was the Director. A lunar impact crater and a main-belt asteroid (1693 Hertzsprung) have been named after him.

It has been reported that Hertzsprung often used to say to his colleagues and students, "If one works hard, one always finds something and sometimes something important."

References

A Dictionary of Astronomy, Oxford University Press, 1997.

A Dictionary of Scientists, Oxford University Press, 1999.

Heilbron, J. L. (ed.), *The Oxford Companion to the History of Modern Science*, Oxford University Press, 2003.

Leuschner, Amin O., "The Award of Gold Medal to Professor EjnarHertzsprung", *Publications of the Astronomical Society of the Pacific*, Vol. 49, No. 288, pp.65-81, 1937 (Available on the net, provided by the NASA Astrophysics Data System).

Spangenburg, Ray and Diane K. Moser, *The History of Science From 1895 to 1945*, Hyderabad: Universities Press (India) Limited, 1999.

Strand, K.A.A., *Ejnar Hertzsprung, 1873-1917*, Publications of the Astronomical Society of the Pacific, Vol. 80, No. 472, pp.51-56, 1968 (Available on the net, provided by the NASA Astrophysics Data System).

The Cambridge Dictionary of Scientists (2nd edition), Cambridge University Press, 2003.

Available sources on the Internet

(This article is a popular presentation of the important points on the life and work of EjnarHertzsprung available in the existing literature. The idea is to inspire the younger generation to know more about Hertzsprung. The author has given the sources consulted for writing this article. However, the sources on the Internet are numerous and so they have not been individually listed. The author is grateful to all those authors whose works have contributed to this article.)

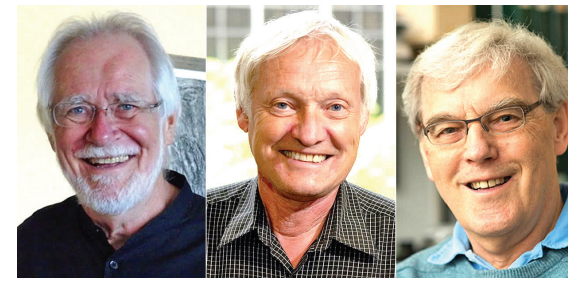
Imaging Living Molecules in Atomic Detail

Biman Basu

Nobel Prize in Chemistry for 2017 was awarded to Jacques Dubochet of the University of Lausanne, Switzerland, Joachim Frank of Columbia University, New York, USA, and Richard Henderson of MRC Laboratory of Molecular Biology, Cambridge, UK. The work of the three laureates has opened up new avenues of research in biochemistry. It has given researchers a unique tool of looking closely at molecules of living systems. The method has taken biochemistry into a new era, making it easier than ever before to capture detailed images of biomolecules.

Ever since it was invented in the early 1930s, the electron microscope's resolution has radically improved in the past decades, from mostly showing shapeless blobs to now being able to visualise proteins at atomic resolution. Since its invention, the electron microscope was the only way to look into the cell and observe minute entities such as viruses that play an important role in our lives. However, the powerful beam of the electron microscope would destroy biological material, so it was believed that such microscopy could only reveal images of dead cells and dead organisms. Also it was then impossible to view solutions under an electron microscope as water would evaporate under the microscope's vacuum.

The situation has now changed, thanks to the work of three scientists – Jacques Dubochet of the University of Lausanne, Switzerland, Joachim Frank of Columbia University, New York, USA, and Richard Henderson of MRC Laboratory of Molecular Biology, Cambridge, UK, who were jointly awarded the Nobel Prize in Chemistry for 2017 "for developing cryo-electron microscopy for the high-resolution structure determination of biomolecules in solution". Cryo-electron microscopy (cryo-EM) is a technique that makes it possible to portray biomolecules after freezing them very quickly so their natural shape is preserved. Here "cryo", short for cryogenic, refers to very low temperatures. Though the actual temperature is not well defined, it is below minus 150°C. In the context of electron microscopy, it refers to the fact that the object to be imaged is cooled to such low temperatures to facilitate being studied under the beam of the electron microscope. The method greatly simplifies and improves the imaging of biomolecules and has brought in a revolution in biochemistry, making it easier than ever before to capture images of biomolecules to atomic details.



2017 Chemistry laureates. (l to r) Jacques Dubochet, Joachim Frank, and Richard Henderson (Credit: 7newsplus.com)

This method is highly effective and has been used to image the elusive Zika virus in recent times. When researchers began to suspect that the Zika virus was causing the epidemic of brain-damaged new-borns in Brazil, they turned to cryo-EM to visualise the virus. Over a few months, three-dimensional images of the virus at atomic resolution were generated and researchers could start searching for potential targets for pharmaceuticals.

The cryo-EM technique allows researchers to freeze biomolecules mid-

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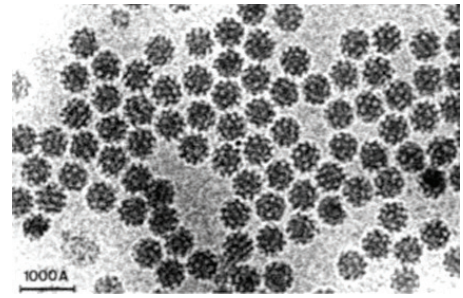
movement and visualise processes they have never previously seen, which is decisive for both the basic understanding of life's chemistry and for the development of pharmaceuticals. It is already helping drug companies to do structures of important mock drug targets, and is being used to understand fundamental biology that can change medicine in the future.

In the first half of the twentieth century, scientists knew that biomolecules – proteins, DNA and RNA – played fundamental roles in the cell, but had no idea what they looked like. It was only in the 1950s, when researchers at Cambridge, UK began to expose protein crystals to X-ray beams, that it was first possible to visualise their complex structures. In the early 1980s, the use of X-ray crystallography was supplemented with the use of nuclear magnetic resonance (NMR) spectroscopy for studying proteins in solid state and in solution. This technique not only revealed their structure, but also how they moved and interacted with other molecules. These two methods also allowed creation of databases containing thousands of models of biomolecules that are used in everything from basic research to pharmaceutical development. However, both methods suffered from fundamental limitations. NMR in solution only works for relatively small proteins and X-ray crystallography can only work with well-organised crystals.

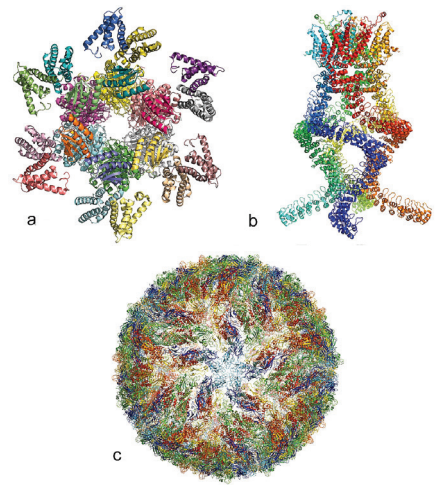
In the early 1980s, Jacques Dubochet, a biophysicist at the University of Lausanne in Switzerland, advanced electron microscopy toward cryo-EM, when he applied a vitrification technique to samples, allowing the biomolecules to retain their natural shape even in a vacuum by cooling the sample using liquid ethane. Since freezing the sample in conventional way would introduce ice crystals, which would disrupt the electron beam and ruin the images, Dubochet found a way to add water to the samples and freeze it so quickly that it formed a kind of liquid glass; this kept the molecules from collapsing and avoided diffracting the electron beam. Rapid cooling solidifies the water in the sample to form a glass instead of crystals. Though a glass appears to be solid, it is actually what is called a 'supercooled' liquid in which individual molecules are arranged at random instead of a periodic crystalline solid structure. Dubochet realised that if he could get water



Dubochet's first images of viruses surrounded by vitrified water (1984).

to form glass – also known as vitrified water – the electron beam would diffract evenly and provide a uniform background.

After the breakthrough in 1982, Dubochet's research group rapidly developed the basis of the technique that is still used in cryo-EM. They dissolved their biological samples – initially different forms of viruses – in water. The solution was then spread across a fine metal mesh as a thin film, which was rapidly cooled in liquid ethane when the thin film of water vitrified around a biological sample, allowing the biomolecules to retain their natural shape



Atomic structures of numerous complicated protein complexes. a. A protein complex that governs the circadian rhythm. b. A sensor of the type that reads pressure changes in the ear and allows us to hear. c. The Zika virus. (Credit: nobelprize.org)

even in a vacuum. In 1984, he published the first images of a number of different viruses, round and hexagonal, that are shown in sharp contrast against the background of vitrified water. Biological material could now be prepared for electron microscopy with relative ease.

In 1975, Joachim Frank, a professor of molecular biophysics and biological sciences at Columbia University, presented a theoretical strategy where the apparently scant information found in the electron microscope's two-dimensional images could be merged to generate a high-resolution, three-dimensional whole. It took him over a decade to realise this idea. In the mid-1980s, he developed algorithms that allowed scientists to enhance electron microscopic images by merging two-dimensional images into higher-resolution, 3-D structures. Frank's image processing method was fundamental to the development of cryo-EM. His image processing method made it possible to analyse and merge the fuzzy two-dimensional images of the electron microscope to reveal a sharp three-dimensional structure. He used this technique to model the surface of the ribosome, the cell's protein synthesis factory. During a press conference following the announcement, Frank told the audience that these are some of the most extraordinary molecules he has ever seen with this method.

Meanwhile, electron microscopy was advancing at a fast pace. By 1975, the best resolution attainable by electron microscopy was 7 Ångström, which was less than the resolution of 3 Ångström obtained by X-ray crystallography. A breakthrough was made by Richard Henderson in 1990 when he produced the first high-resolution model of a protein, bacteriorhodopsin (a purple-pigmented protein that is found in the outer membrane of a bacterium that converts light energy into chemical energy in the synthesis of ATP), thereby proving that cryo-EM could provide images as detailed as those generated using X-ray crystallography, which was a crucial milestone. In 1995, he wrote an article in the *Quarterly Review of Biophysics* suggesting that this technique could one day be used to image biological molecules at atomic resolution.

The work of the three laureates has opened up new avenues of research in biochemistry. It has given researchers a unique tool of looking closely at molecules of living systems. The method has taken biochemistry into a new era, making it easier than ever before to capture detailed images of biomolecules. It has enabled drug companies to design structures of important mock drug targets, and to understand fundamental biology that can change medicine in the future. ■

Conserving Water on Day-to-Day Basis Can Help in a Big Way

M. A. Haque

We are aware that in days to come water availability will be a very important factor in many countries and societies. India will be one of them. Consequence of water shortage is the prevalence of health problems linked to lack of sanitation. Scarcity of water leads to insanitary habits which in turn cause so many health problems, especially among children. Hence, we must try all possible means to conserve available water and also economise on water consumption. Avoiding wastage can help in a big way in meeting the goal.

After the 2017 monsoon was over it became obvious that the country had received below-normal monsoon that year. The monsoon season had ended with about 5.2% deficit. About 50% of the districts received normal rains while more than a third, i.e., about 215 districts had deficient rainfall. The shortfall had impacted agriculture as well as other activities. An important issue was that during the first half of monsoon (June to July, 2017) the rainfall was surplus by about 2.5%. But during August and September there was deficiency to the extent of 12.5%. As a consequence large areas suffered. Majority of districts which received deficient rains were in Haryana, Madhya Pradesh, Punjab, Uttar Pradesh and Vidarbha region of Maharashtra.

The India Meteorological Department has predicted that the southwest monsoon for the country would be normal for the year2018. The forecast is that the total precipitation could be 97 per cent of the long period average (LPA). But we need to remember that there is always a possibility of 5% error on either side in this kind of prediction. It means that the normal monsoon may be within a range of 96-104% of the LPA. But we need to be careful in reaching any conclusion as it is too early to make any definite prediction. More reliable information will be available only by June-July, 2018. Till that time we need to keep our fingers crossed. Reason is obvious. Last year, in 2017, the prediction was for normal monsoon. But the end result was that there was deficiency of about 5.2% and certain areas had to suffer much more.

Another issue is that when we talk about monsoon and rainfall, we take the country average or regional averages. The overall picture may not be very disturbing. But India being a large country with so much of variations,it may show different pictures for different areas. Hence, average figures at times prove deceptive. A third issue is that India gets rains and other forms of precipitation for only about three months. About 75% of the total precipitation pours during these months. For the rest of the year there is little rain and other forms of precipitation.

The issue of immediate concern is that because we get rain, snow, etc., for very short duration, it is just not possible to utilise the water fully. The only solution is that we need to make arrangements for collection and storage of the water so received so that we could be comfortable for the rest of the year till the next monsoon. We need to work in reverse to the age old proverb: "Saving for the rainy days". In this case we need to save for the dry days. But the tragedy is that we have been neglecting that aspect miserably. Most of the water received from the sky is not stored and it is lost to the seas and oceans. In the process the water also creates various problems like soil erosion, land degradation and floods.

There are a few very easy and practical methods of conservation of the available water resources and about augmenting the water resources with water collected from the atmosphere, which will be discussed

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here. These are simple techniques and these can be adopted by everyone. If we adopt these techniques,they can help the country in combating water scarcity to some extent without much expense or effort.

Age-old expression

There's another old expression that says "You don't need to reinvent the wheel," meaning that we don't need to create something that already exists. This is a good rule of thumb. But quite often we tend to forget certain things with time, especially if they do not look to be modern. We find new appliances and equipment and we start using them. In the process the old ones are forgotten or discarded. It happens in almost every avenue of day-to-day life. However, the situation has changed and we need to bring back and revive the old techniques. Also, there may be a possibility that the old systems or methods can be refurbished and used in the new circumstances. Here we are going to discuss about a few simple techniques. These can be easily adopted at household level or at community level without installing costly equipment and without much extra effort. These are based on the principle: *Every drop of water saved will be an added resource.*

Air-conditioning system water

In recent years air-conditioners have become quite popular on account of falling price of air-conditioners, better availability of power and increase in affordability. Also, the shrinking size of dwelling units and changes in architecture are forcing people to go for air-conditioners. In all types of air-conditioners there are outlets which allow the condensed water to flow out. When the machine cools the air, some of the water vapour present in the air gets condensed over the cooling coils. The water first collects at the base of the machine and then flows out through the outlet almost continuously. The water may seem to be small in quantity but in a few hours or the whole day, the quantity becomes substantial. In case of larger machines such as those used in offices, business establishments, etc., the quantities of condensed water are much more. In hot, humid weather, such machines may produce up to 90 litres of water per day. If we look at the physics of the process, the water that condenses is distilled water as it is the water vapour that condenses and flows out. At present, the condensed water is allowed to go to the drain, i.e., it is wasted.

We can very well utilise this water in several ways. In case of storage batteries that need topping up, the condensed water is ideal. We normally purchase battery water from market. So, we will save money, energy and also water. The condensed water can be utilised for washing clothes. Generally the water that is available to us has dissolved salts in different concentrations, which make the water less efficient with soap or detergent. If we use distilled water, with the same quantity of soap or detergent, we will get better results. In old times households used to collect rain water in large containers and the water was used for washing clothes. Reason was same. Rain water is free from dissolved salts. As a result washing used to be easy and more efficient.

In case of larger communities with central air-conditioning, the quantity of water is huge. Currently the water generally goes waste. If some planning is done, the water can be used for irrigation of lawns, flower beds and kitchen gardens, etc., or it can be used to recharge ground water simply by connecting the outlet/s to the ground water recharge facilities. It will have the added advantage that recharge will continue even in hot summer when there is no or very little rain in most of India.

Use of PET bottles for irrigation

In cities and towns the dwelling units are becoming smaller. There is no land for growing flower plants or other types of plants. But people want to have these plants for aesthetic purposes. Many families are interested in growing vegetables and fruits too to get products free from chemicals. They have no option but to use earthen, cement or plastic pots for the purpose. They have to irrigate the plants regularly, especially in summer. Sometime the pots have to be irrigated twice in a day. The requirement of water on daily basis is quite large, depending on the number of pots and the types of plants. In most of the cities and towns water supply is limited. As a result it is a difficult task to keep the potted plants growing or at least surviving during the summer months.

We can adopt a simple technique which will reduce the quantity of water required and also help the plants to survive better. We can take discarded PET bottles, cut the base of the bottles and make one small hole each in the caps of the bottles. The caps can be placed in their usual positions and the bottles are to be placed in the pots upside down so that the necks of the bottles are buried in the soil. The bottles can be filled with water and left. The water will go out of the hole in the caps and reach deep in soil, close to the roots. The plants will get water that they require and they will get water slowly. The same quantity of water will suffice for much longer than normal sprinkling on the surface of the soil because the water will seep directly to the root zones. As a result the water will be utilised more efficiently. Also, there will be less evaporation from soil and consequently reduced wastage.

Also, it is common to find that water trickles out of the base of the pots if irrigation is done in excess. The water is wasted and makes the surface where the pots are placed dirty. All these problems will be solved in one stroke. Care has to be taken to select the bottles according to the size of the pots. For smaller pots 500 ml bottles may suffice while for larger ones one litre or even larger bottles can be used. Through hit-and-trial in a few days it can be ascertained how long the water lasts in the bottles and how often the plants have to be irrigated. In any case, there will be reduced effort and certainly reduced requirement of precious water.

This technique can be adopted for small gardens or farm holdings too, including kitchen gardens. Bottles have to be fixed

at intervals close to the plants. Water has to be filled in the morning and left to seep out. This technique will prove more useful where individual plants have gaps between them,such as fruit plants, climbers, bushy plants, etc. Bottles can be placed close to the plants. At the end of the day a great deal of saving will be there on irrigation water, effort, and also energy. Survival of plants will also be better in harsh summer as water will reach the root regions directly.

RO system discharge water

Due to increasing incidence of water-borne diseases and inefficiency of the municipal water supply systems, more and more people are installing RO (Reverse Osmosis) filtration systems for water. Depending on the requirement the sizes and capacities are decided. In households small ones suffice while for larger communities larger sizes are installed. Then there are commercial establishments which supply bottled water to consumers. There the installations are very large.

In almost all RO systems there is discharge of 'waste' water parallel to the collection of filtered/purified water. The purified water is utilised while the waste water is discarded. Generally it flows to the drains or goes into the sewer system. The quantity of waste water is directly proportional to the quantity of dissolved materials in the supply water. If the quantity is high, the quantity of waste water will be larger. At individual household level the quantity may seem small but on community level the quantity is quite large and in any case the water is wasted.

Of course, the water cannot be used for drinking or cooking, etc. But it can be used for other purposes. For example, it can be used for cleaning utensils. Although it may not be necessary, at the end the utensils may be rinsed once with normal water to remove any excess salts left on the utensils. Also, the water can be used for irrigating lawns, kitchen gardens or potted plants. If the salt content of the waste water is very high, it may be mixed with normal supply water for irrigation. The quantity of total salts can be easily measured by the suppliers of the equipment. When they come for installation, they assess the salt content of supply water, filtered water and also of waste water. Hence, decision can be easily taken regarding the pattern of use, especially for irrigation. Another way is to take a little water in the mouth. If it is not very saline, it can be used for irrigation directly. Otherwise it can be mixed with supply water in different proportions. But in any case the water will not go waste.

Use of water pot with spout

Not till long ago households used to have water pots made of brass, copper, aluminium or some other material. There were two varieties. One was a simple pot with a single wide mouth. The same was called *lota*. May be some of us will remember the famous story entitled "Akbari Lota". That was a satire on the English people ruling India about how they could be fooled easily. The other variety was almost same except that it had a small spout for water to flow out. The spouted one was more efficient as the water could flow only slowly and in controlled and pointed way. Majority of households used to have either of the two types for different use. With the advent of taps, wash basins, toilet showers, etc., the pots were slowly discarded, especially from urban areas. But we need to re-invent them. Particularly useful are the ones with spout as their re-introduction can save lot of precious water on day-to-day basis. Somehow it happened that the spouted pot was associated with Muslim culture and it became restricted with Muslim families and institutions. For example, even now most mosques, especially in small towns and rural areas, have them for ablution (washing of hands, face, feet, etc., before prayers). Reason is the same, i.e., conservation of water, as water has to be drawn from dug well or hand pump or brought from outside. In urban mosques there are taps for the purpose. Till few decades back I used to see those pots made of copper in *Piaos* (kiosks which provided free drinking water) on roadsides and in temples, etc. The idea was to restrict wastage of water. Also, I have seen them in temples and *Pooja ghar* in Hindu households. There too the pots were generally made of copper. May be it can be found in many homes even now. About three decades back when I visited Lucknow University I had seen those pots in the toilets. May be they are still in use in places where Muslim influence is strong. Generally it was made of brass or aluminium. However now it is commonly made of plastic. Also, cheaper versions are available which are locally made by metal workers from discarded containers. If we compare the quantity of water needed to do the same job with a spouted pot against the quantity of water needed from a tap, the ratio may be ¼ or even less. As such it may not seem to be important. But if we estimate the saving on daily basis in a household or in a community, it will be mind-boggling.

Conclusion

We are aware that in days to come water availability will be a very important factor in many countries and societies. India will be one of them. According to the National Commission for Integrated Water Resources Development (NCIWRD) about 83% of available fresh water in the country is used for irrigation. The rest 17% meets the demand for domestic, industrial and other sectors. For the year 2050, the Commission has estimated that the demand will grow to 1,180 billion cubic metres. It will be very difficult for India to meet the demand. A less known consequence of water shortage is the prevalence of health problems linked to lack of sanitation. Scarcity of water leads to insanitary habits which in turn cause so many health problems, especially among children. Hence, we must try all possible means to conserve available water and also economise on water consumption. Avoiding wastage can help in a big way in meeting the goal. ■

Artificial Intelligence – Changing the world like never before!

Udit Malik

AI has made decision-making easier than never before. It is reducing human errors and increasing efficiency in a process. It is helping a dumb to speak and helping a paralysed person to express his/her thoughts. Smart phones, intelligent gadgets, drones, robots, and satellites are some of the daily life examples of intelligent machines. Applications of AI in manufacturing, health care and finance are numerous. But with all these positives aspects of the technology, there is a serious debate associated with AI. For example, technological advancements have always led to the human job threats.

Human race has been developing various technologies to change its life style. Some technologies have drastically changed the world and living behaviour of humans. From the discovery of wheel, to engines to computers –all such disruptive technologies have contributed in shaping today's world. What next? The smart gadgets, machines, and robots are now winning the world and changing human life. These all are the gifts of technology collectively known as Artificial Intelligence (AI).

Artificial Intelligence is an area of computer science. It focusses on creating intelligent machines that can perform tasks like human brains or even better than that. AI is across-domain technology of different branches like statistical analysis and machine learning, pattern recognition, logic and probability theory, biologically motivated approaches such as neural networks, evolutionary computing or fuzzy modelling, and the like. Using these approaches different types of basic functions are attained by the AI technology. A few examples include learning, reasoning, classification, prediction, problem-solving, language comprehension, hypothesis generation, and the list is endless.

The vague description of a metallic intelligent creatures can be found in Greek mythology. Talos was a creature made of bronze metal, created to protect the Europa in Crete from pirates and invaders. The industrial revolution and World Wars I and II led to the great advances in technology. In 1948, British mathematician Alan Turing in his *Intelligent Machinery* wrote "My contention is that machine can be constructed, which will simulate the behaviour of the human mind very closely". In 1948 and 1949, the American-born British neurophysiologist and robotician William Grey Walter created the first ever robot named Elmer and Elsie. These robots were called tortoises because of their slow movement. They possessed the ability to move in the direction of light. But the term artificial intelligence was first coined by American computer scientist pioneer and inventor John McCarthy in 1956 at Darmouth Conference of Stanford University. And a race started to build a machine with general intelligence compared to that of human beings.

Despite many efforts being put by the scientific community, the quest for AI appeared to be in danger by early 1970s as there were no satisfactory advancements despite heavy investments by the governments. In 1980s the AI took a different turn into a specific business solution. Rather than creating a machine with general intelligence a system was created for performing a pre-decided set of tasks. Digital Equipment Corporation was one of the few organisations to realise the benefit of AI. But such kinds of expert systems were not comparable to that of biological intelligence of humans/animals. In 1990, Australian roboticist Rodney Brooks published a paper "Elephant don't play

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chess". He argued that pre-programming of machine with intelligent instructions to attain the desired task was a wrong attempt, and he called for an approach known as 'Behaviour-based' approach that helped in creating more intelligent robots.

Since then, AI has travelled a long way. Smart phones, intelligent gadgets, drones, robots, and satellites are some of the daily life examples of intelligent machines. But are these the only applications of such an intelligent technology? The answer is obviously no. The applications of AI are numerous and the technology has also started challenging humans in many spheres.

Panorama of AI applications

Many science fiction cartoons are just a few years away from reality now. Covering all spheres of AI applications will be a difficult task, so we discuss only a few common applications of AI.

Gaming –In gaming the most common use of AI is to create a non-player character or a machine player. The machine player uses a pre-set of instructions to play with the human player. But with the machine learning techniques, the machine player can learn from its previous experiences and can improvise its performance in next rounds.

Speech recognition – Every one of us must be watching the advertisements of Google and other companies that ask you to speak on the mobile and it will answer you. That is speech recognition. With machine learning abilities, the search engines are able to provide you the best results. The United Airlines has replaced the keyboards for flight information and uses the speech recognition of flight numbers and city names. This capability can also be used to dictate instructions to the computers.

Manufacturing – Almost all manufacturing units now use machines, which are getting automated, thereby reducing the time and cost involved in the production of goods. Foxconn, the technology giant that supplies gadgets to Apple, Google and Amazon, employed 10,000 robots to balance the labour cost. Digital designing of doors, 3D printing of instruments and drugs are some other examples in this domain.

Finance – There are multiple uses of AI in finances. It is employed by banks to ensure secure transactions and to prevent frauds. AI is also used to process and understand the large data that is generated in the finances process, enabling the quick data processing and understanding.

Transportation – AI is also changing the ways we use transportation. Online maps are now available that show us the route to our destination. They even suggest the shortest way and make us aware of the potential road jams. Driverless cars/trucks are also hitting the roads. It may not be far when driver-less cars become a common sight on the roads. The surcharge fares during rush hours charged by mobile app cabs are also an example of use of AI technology.

Military –AI is being used to reduce the loss of life during wars. Intelligent weapons are already in place. Intelligent soldier robots are under research that can be used instead of human soldiers. Drones and smart vehicles are already being used by the military.

Healthcare – Health care is one of the most active industries that use AI. Some of the health care applications are given below:

Diagnosis – MRI, CT scan, and ultrasound are some of the most commonly used image-based diagnostic tools. Different algorithm based AI interfaces are available that predict the abnormalities and avoid false negative in the results. Google parent company had developed an AI that helps in detecting the cancer, which earlier could have been possible by experts only.

Robot Assisted Surgery – Similar to mechanical workshops, robots are being deployed in surgeries also. Robot assistance in surgeries has made it possible to do surgeries with minimal penetration and high precision. This has resulted in faster recoveries, shorter hospital stays and less pain.

Drug development – Drug development is a very tedious and long process. It takes about 20 years for a drug to come to market after passing through all the phases. With the help of AI, drug development is becoming much easier and less time-consuming. AI is being used in various phases of drug development. With the help of AI, identification of potential drug molecules, drug targets, and optimal formulation has become easier.

Bioinformatics – A field of that use the knowledge of biology and computers together. The use of AI has made the understanding of cells physiology and biochemistry easier. AI is being used to create a virtual cell.

Apart from the above, AI is also being deployed in providing nursing assistance, hospital management, laboratory works.

Education – Complementing class teaching is one of the applications of AI in education. Different students have different progress rates. And teachers find it hard to deal with the individual educational needs of their students. Machine learning algorithms have been developed that provide insights and help teachers to identify gaps in their teachings and point where student are struggling.

Scientist robots – In 2009, scientists from the University of Cambridge and Aberystwyth University created a robot scientist named Adam. The robot was created to perform end–to-end activity involved in research without any human intervention. The robot had worked on the baker's yeast. Using AI it has predicted that there are some specific genes involved in catalysing biochemical reaction. The next robot Eve will be more advanced than Adam.

The above describes just a few handful applications of AI. AI has made decision-making easier than never before. It is reducing human errors and increasing efficiency in the process. It is helping a dumb to speak and helping a paralysed person to express his/her thoughts. But with all these positives aspects of the technology, there is a serious debate associated with AI. For example, technological advancements have always led to the human job threats. And AI posesa major threat like never before. Recently many IT companies have been firing thousands of their employees as a result of introduction of advance technologies that no longer need human professionals. In 2016, Foxconn replaced 60,000 factory workers with robots. Apart from jobs risks, there is more serious question. If the robots become smarter than humans, can they eliminate human race? As Stephen Hawking had said, "The development of full artificial intelligence could spell the end of the human race."

Our Buzzing Friends

Ankita Ray

Bees and other pollinating insects play a major role in our ecosystem. One-third of the food production is dependent on the pollinators. Without pollinators, crop production would be under major threat as hand pollination is extremely slow, requires a lot of labour and economically is not feasible. Economic value of pollination carried out by bees is estimated at $311 billion annually around the globe!It has been reported that the bee population is on a decline.

We often hear a buzzing sound while sitting in a garden or in our balconies planted with beautiful bright flowers attracting our winged friends– the bees. Bees belong to the order Hymenoptera (*hymen* = membranous, *ptera* = wings); other members include wasps, saw flies and ants. Whenever we come across the word 'bee' we start thinking about the honey bees. But the fact is, apart from honey-producing bees, which belong to the genus Apis, there are several other bees (generally known as non-*Apis* bees) which do not produce honey but only act as pollinators. (The Indian honey bee is scientifically known as *Apis cerana indica*.) Honey bees form colonies and lead a social life whereas the other families tend to stay aloof and maintain solitary lives. Other relatives include Megachilidae (leaf cutter bees), Halictidae (sweat bees), Andrenidae (miner bees), bumble bees, carpenter bees, stingless bees, which contribute significantly towards pollination.

How other bees differ from honey bees?

There are some morphological (physical) differences between honey bees (*Apis*sp.) and non-*Apis* bees. Honey bees, bumble bees have their specialised pollen-carrying comb-like structures known as corbicula on their hind legs (generally called the pollen basket) where they collect the pollen and take it back to their hives to nurture their young ones. On the other hand some bees, for example the family Megachilidae carry their pollen on the underside of the abdomen, the members of the family Halictidae and Andrenidae carry it on their hind legs. Honey bees do not survive after stinging because their sting is barbed; once the sting enters the skin, the bee is not able to pull it out and the bee dies. The other stinging bees do not generally die as their sting is not barbed. Also, unlike the sting of honey bees, which is painful, sting of other bee families is mild. Nature has provided honey bees with a good defence mechanism as compared to the other non-*Apis* bees probably because honey bees have honey in their hives to protect

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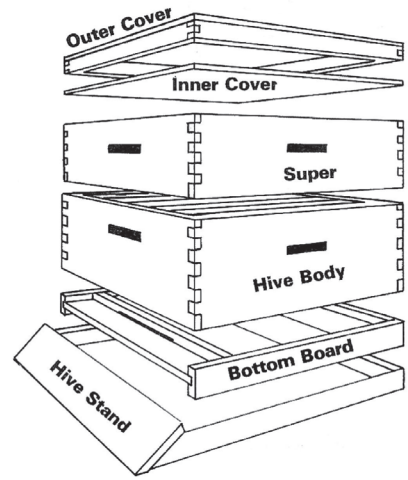
from natural predators. There are several other morphological (physical) differences between the *Apis* and non-*Apis* bees, the ones mentioned above are non-technical differences.

Comparison of the nesting pattern

Honey bees lead a highly social life. They build their hives in caves, rock cavities and hollow tress and even under concrete parapets. Their hives are divided into hexagonal compartments or cells made of wax which hold the larvae and store the honey and pollen. The larvae or the young ones are fed on honey produced from nectar and pollen collected from flowers. The queen is only fed on royal jelly, a nutritious substance produced by the worker bees that is used in the nutrition of larvae, as well as adult queens. The other non-*Apis* bees lead solitary lives. They do not have such level of organisation in their hives. They are generally ground nesting bees, building their nests in hollow soft wood cavities or tunnels in ground. Nest building materials include leaves, hairs, plant resin etc.

Life cycle of honey bees

The life cycle of honey bees consists of four stages– egg, larva, pupa and adult. The adults include the queen, workers and drones. The queen performs the sole function of laying eggs. Workers are females performing all the activities needed for maintenance of the hive, i.e., construction of nest, feeding the young ones, taking care of the hive whereas the drones are males whose duty is to search for a female and mate with it. Only one queen is present in a hive. The queen is fed on royal jelly by the workers. After fertilisation, the queen lays its eggs. Males, called drones, emerge from unfertilised eggs, and females emerge from fertilised ones and become the workers. Within the colonies exists division of labour among the workers, like nurses and foragers.



A typical artificial bee hive (source: www.ukey.edu)

Nurses build up, clean and protect the hive as well as feed the younger ones; while the foragers move out of the hive and visit the flowers in search of nectar and pollen. This kind of division in labour does not exist in non-*Apis* bees as they are solitary in nature.

Life cycle of honey bees

Honey is produced from the nectar of the flowers visited by the bees. After feeding, the nectar is stored in the crop of the stomach and acted upon by the enzymes that modify its chemical composition. On returning to the hive the bee passes the nectar to another bee through regurgitation and this process is repeated until it is deposited in the combs of the hive. The nectar is still viscous in nature. The extra water is taken out by fanning the combs with wings. When most of the water has evaporated the bees seal comb with a secretion from their abdomen which hardens to turn into wax.

Bee keeping

Beekeeping or apiculture is the management of honey bee colonies. Apiculture is done for collection of honey and other bee products such as bee wax. Not all species of honey bees can be domesticated since many of them are highly aggressive. Species of bees used in beekeeping are *Apisdorsata*, *Apismellifera*, *Apisindica*, *Apisflorea*. A typical domesticated man-made bee colony consists of a hive stand, bottom board and eight to ten parallel frames of honeycomb cells that contain the eggs, larvae and pupae. The hive stand forms the base of the colony and elevates the whole structure above the ground. The bottom board serves as the floor of the colony and as a taking off and landing platform for the foragers. The hive also consists of the queen excluder that allows the worker bees but not the queen to traverse the barrier so as not to reach the honey supers (part of a commercial or other managed beehive that is used to collect honey. The main body consists of the parallel frames. The outermost honey combs on both the sides are exclusively for long term storage of honey and pollen. Separate boxes are kept above the brood box in which surplus honey produced by the honey bees is stored. In this way honey can be removed without disturbing the bees.

A beekeeper performing apiculture

Conservation and awareness

Bees and other pollinating insects play a major

role in our ecosystem. One-third of the food production is dependent on the pollinators. Without pollinators, crop production would be under major threat as hand pollination is extremely slow, requires a lot of labour and economically is not feasible. Economic value of pollination carried out by bees is estimated at$311 billion annually around the globe! It has been reported that the bee population is on a decline. There may be several factors responsible for the dwindling bee population such as habitat fragmentation, use of pesticides, climate change and attack by parasites and pathogens. Use of high doses of insecticides is the major reason behind the collapse of the bee population in many areas. The negative effects of insecticides on bees are many and include physiological effects which alter the developmental rates such as delay in reaching adulthood, effects on navigation and learning behaviour, interference in feeding behaviour, inability in recognition of flower and nest location or spatial orientation.

A beekeeper collecting honey

How we can help

- Planting a pollinator garden. Providing variety of native flowering plants, shrubs, wild flowers that bloom successively throughout the season. Avoiding pulling out shrubs, bushes and hedgerows as they are potential foraging and nesting sites for the bees.
- Providing nesting sites such as hollow wooden logs and canes for solitary bees.
- Not using pesticides or using organic pesticides if necessary and applying it when pollinators are least active, i.e., before dawn and after sunset.

Plant garden for honey bees

- Planting native flowering plants in the garden. Native pollinators and native plants have become mutually adapted to each other through course of time and planting the right plant makes a huge difference to the pollinators.
- Joining a pollinator friendly organisation to discover more about pollinators and their flowers.

Some interesting facts about bees

- Only the female bee stings. The ovipositor or the egg-laying organ of the females is modified as a defensive weapon.
- Honey bees uses waggle dance in the figure of 8 to communicate the distance between the food source and the hive to other members of the hive.
- Bees are fabulous flyers. They can fly up to 25km per hour beating their wing 200 times per second.
- Scientists have found that a toxin present in the venom released by the bee sting can kill HIV by destroying the envelope of the virus.
- Bees use Sun as the compass to determine directions and measure angles between their food source and the hive.
- Honey bees have exceptional olfactory abilities to recognise signals from other members of the hive and odour recognition for finding food.

Recent Developments in Science and Technology

Biman Basu

Whenever we think of DNA, we mostly have in our mind a picture of the well-known double-helix, a twisted ladder-like structure. But it has been known for a long time that DNA also comes in other shapes as well, though none has been detected within human cells. Now comes the news of the discovery of a new form of DNA – a four-stranded knot-like structure called an 'i-motif'– in human cells.

Galaxy without dark matter detected

Dark matter is an enigmatic entity that has mass but is invisible because it does not interact with light. The primary evidence for dark matter came from calculations which showed that many galaxies would fly apart instead of rotating, or would not have formed or move as they do, if they did not contain a large amount of unseen matter. In fact, till recently it was believed that galaxies and dark matter go together and there cannot be one without the other. Without dark matter, theoretical models of our universe simply wouldn't add up. But the idea that dark matter is an essential ingredient for galaxies to form is being challenged by the discovery of a distant galaxy that seems to contain no – or almost no – dark matter. Dark matter cannot be seen or touched, but it outweighs all the normal matter in the universe by more than 5 to 1. Astronomers know it's there because of its gravitational influence, but they cannot detect it any other way.

The discovery of the sparse, see-thru galaxy called NGC1052-DF2 was made by astronomers using the Dragonfly Telephoto Array – a New Mexico-based telescope built of camera parts that is designed to detect very faint galactic structures. The astronomers then followed up the analysis, collecting more data using the Hubble Space Telescope as well as the Gemini North and Keck Observatories in Hawaii (*Nature*, 29 March 2018, | DOI: 10.1038/nature25676). It is the first galaxy detected to contain little or no dark matter.

According to Pieter van Dokkum of Yale University in New Haven, Connecticut, USA, who led study, NGC 1052-DF2 is as large as our Milky Way, but it had escaped attention because it contains only 1/200th the number of stars. Moreover, it contains only about 1/400th the amount of dark matter that astronomers had expected. Given the object's large size and faint appearance, astronomers classify NGC 1052-DF2 as an 'ultra-diffuse galaxy'.

This large, fuzzy-looking galaxy is so diffuse that astronomers call it a "see-through" galaxy because they can clearly see distant galaxies behind it. Its lack of dark matter may explain why. (NASA, ESA and P. van Dokkum / Yale University)

Van Dokkum and his team spotted the galaxy with the Dragonfly Telephoto Array, a custom-built telescope in New Mexico they designed to find these ghostly galaxies. They then used the W.M. Keck Observatory in Hawaii to measure the motions of 10 giant

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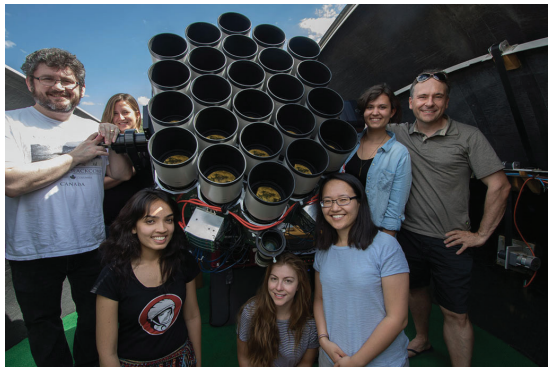


The Dragonfly Telephoto Array is a robotic sky-watcher that peers into space from New Mexico through several regular Canon lenses all working together. (Credit: University of Toronto and Yale University)

groupings of stars called globular clusters in the galaxy. This study revealed that the globular clusters were moving at relatively low speeds – less than 37,000 kilometres per hour. On the contrary, stars and clusters in the outskirts of galaxies containing dark matter move at least three times faster. From these measurements, the team calculated the galaxy's mass. "If there is any dark matter at all, it's very little," van Dokkum explained. "The stars in the galaxy can account for all the mass, and there doesn't seem to be any room for dark matter."

The researchers next used NASA's Hubble Space Telescope and the Gemini Observatory in Hawaii to uncover more details about the unique galaxy. Gemini observations revealed that the galaxy does not show signs of an interaction with another galaxy. Hubble observations helped them better identify the globular clusters and measure an accurate distance to the galaxy. The Hubble images also revealed the galaxy's unusual appearance.

The ghostly galaxy, about 65 million light-years away, doesn't have a noticeable central region, or even spiral arms and a disk, typical features of a spiral galaxy. But it doesn't look like an elliptical galaxy, either. The galaxy also shows no evidence that it houses a central black hole. Based on the colours of its globular clusters, the galaxy is about 10 billion years old.

New plastic-eating enzyme to clear plastic pollution

Plastic is a well-known and widespread pollutant that is causing untold harm to the Earth's ecosystem. In less than a century of coming into market, plastics have become essential to modern society, driven by their incredible versatility coupled with low production costs. It is, however, now widely recognised that plastics pose a dire global pollution threat, especially in marine ecosystems, because of the ultra-long lifetimes of most synthetic plastics in the environment. Environmentalists have detected as many as six huge floating garbage patches – mostly discarded plastic bottles – swelling in the ocean. About 1 million plastic bottles are sold each minute around the globe and, with just 14% recycled, many end up in the oceans where they have polluted even the remotest parts, harming marine life and potentially people who eat seafood. Even areas as far removed from civilisation as the Arctic are not safe. In fact, we are slowly suffocating a lot of natural ecologies with our trash. It is estimated that fish, birds, and other animals all unwittingly consume the five trillion tons of plastic strewn about the ocean and often get killed. Experts estimate that by 2050, there will be as much waste plastic in the ocean by mass as there are fish.

While plastics such as poly(ethylene terephthalate), commonly known as PET, are highly versatile, their resistance to natural degradation presents a serious, growing risk to fauna and flora, particularly in marine environments. PET is one of the most abundantly produced synthetic polymers and is accumulating in the environment at a staggering rate as discarded packaging and textiles. The properties that make PET so useful also endow it with an alarming resistance to biodegradation, likely lasting centuries in the environment.

The problem of proper disposal of plastic waste has been engaging the attention of scientists for a long time. Now researchers from Britain's University of Portsmouth and the US Department of Energy's National Renewable Energy Laboratory (NREL) have created – by accident – a new enzyme capable of breaking down plastic bottles. The breakthrough could help solve the global plastic pollution crisis by enabling for the first time the full recycling of bottles. (*Proceedings of the National Academy of Sciences*, 12 April 2018 | doi.org/10.1073/pnas.1718804115).

The new research was spurred by the discovery in 2016 of the first bacterium called *Ideonellasakaiensis* at a waste dump in Japan that eats one of the most common forms of plastic, PET, found in water bottles, food containers, and polyester. Scientists have now revealed the detailed structure of the crucial enzyme produced by *I. sakaiensis*, which they call PETase. After characterising the structure of the enzyme by bombarding it with high-power X-rays, the team changed the structure of PETase slightly in order to compare it to another enzyme which breaks down cutin (a polymer used as a protective coating in plants). That process unexpectedly conferred on PETase a 20-percent improvement in its capacity to degrade PET. According to the researchers, the new mutant enzyme takes just a few days to break down PET, compared to the 450 years it takes for the stuff to degrade naturally. The researchers are optimistic this can be speeded up even further and become a viable large-scale process. A patent has been filed on the specific mutant enzyme by the Portsmouth researchers and those from the US National Renewable Energy Laboratory in Colorado.

"What we are hoping to do is use this enzyme to turn this plastic back into its original components, so we can literally recycle it back to plastic," said Prof John McGeehan, at the University of Portsmouth, UK, who led the research. "It means we won't need to dig up any more oil and, fundamentally, it should reduce the amount of plastic in the environment."

Genetically modified plant yields more antimalarial compound

Despite widespread use of pesticides and other steps to check the breeding of mosquitoes, malaria remains a global health problem. According to the World Health Organisation (WHO), in 2016 alone malaria affected approximately 216 million people in 91 countries and caused an estimated 445,000 deaths worldwide. *Plasmodium falciparum* is the most prevalent malaria parasite and is responsible for most malaria-related deaths globally. The compound artemisinin is an effective anti-malarial compound that is synthesised by the Chinese medicinal plant *Artemisia annua*, commonly known as sweet wormwood. According to the WHO, the best available treatment for malaria, particularly for cases

Artemisia annua cultivation (Credit: Ying Liu, Shanghai Xinhua News Agency)

caused by *P. falciparum*, is artemisinin-based combination therapy (ACT).

Currently, the supply of artemisinin for ACTs is mainly dependent on the agricultural production of the compound. However, plant-based production sometimes cannot meet the global demand due to the low amount of artemisinin produced in *A. annua* leaves (0.1%-1.0% of dry weight). Alternatively, a semi-synthetic system can be used for the production of artemisinin, in which yeast are engineered to synthesise its precursor, artemisinic acid. However, the semi-synthetic production of artemisinin is expensive and thus cannot replace its agricultural production at present. Hence, there is a considerable interest in increasing the artemisinin content of *A. annua* and an urgent need to identify other potential anti-malarial compounds.

Now Kexuan Tang, a plant scientist at Shanghai Jiao Tong University, and colleagues have been able to genetically modify the Artemisia plant, coaxing it to produce more than three times the amount of artemisinin naturally produced in leaves. The researchers generated a high-quality draft assembly of the 1.74 gigabase *A. annua* genome, which contains 63,226 protein-coding genes, one of the largest numbers among sequenced plant species. It took several years to complete the genome sequence due to its large size and high complexity. The researchers then identified three genes crucial to artemisinin production. Genetic modifications to increase the activity of these genes boosted the artemisinin level in leaves from 0.1%-1% of their dry weight to 3.2% (*Molecular Plant*, 24 April 2018; DOI: 10.1016/j.molp.2018.03.015).

However, before the work could have an impact on commercial production it will require extensive field trials to demonstrate that the engineered plants perform in the field as well as they have done under experimental conditions. Besides, the genetically modified plant will have to obtain regulatory approval before it can be commercially grown anywhere.

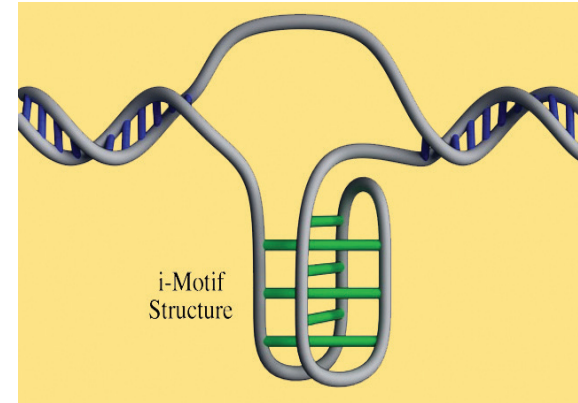
Strange DNA discovered in human cells

Whenever we think of DNA, we mostly have in our mind a picture of the well-known double-helix, a twisted ladder-like structure. But it has been known for a long time that DNA also comes in other shapes as well, though none has been detected within human cells. Now comes the news of the discovery of a new form of DNA – a four-stranded knot-like structure called an 'i-motif'– in human cells. Scientists had known about i-motif DNA earlier, but only under lab conditions. The i-motif structure was first observed around two decades ago, in lab conditions that were quite acidic, and most scientists assumed the i-motif would probably never be found in nature. However, in recent years, studies have pointed to the possibility that this bizarre form of DNA could, in fact, exist in living humans and a new study led by Marcel Dinger, head of the Kinghorn Centre for Clinical Genomics at the Garvan Institute of Medical Research in Sydney, Australia provides the first direct evidence that it does exist and that it may play an important role in regulating our genes (*NatureChemistry*, 23 April 2018 | doi:10.1038/s41557-018-0046-3).

According to the researchers, this is how the i-motif forms: Imagine a small section of the DNA double-helix where the hydrogen bonds that connect the two major strands come apart while the helix suddenly untwists. If one of the strands is full of cytosine (one of the four major nucleic acids that makes up DNA), it will loop outward like a tied shoelace and hydrogen bonds would form within the loop itself, binding those cytosines to one-another (instead of to guanine, as is normally the case in the double-helix). Thus they essentially form a scaffold, where each C-C bond is 90 degrees to its corresponding C-C pair.

To confirm the presence of these i-motifs in human DNA and pinpoint their locations, the Sydney team created a special fragment of an antibody molecule capable of binding to the i-motif structure. They then used fluorescent techniques to highlight the antibody molecules under the microscope. This study demonstrated that these i-motifs can indeed form in nature. In the study, the researchers found that the i-motifs were present in gene promoter regions and telomeres, suggesting that they regulate the genome.

A unique feature of the i-motifs observed by the researchers was that their folded shape was not permanent; they folded into existence and then unfolded, repeatedly. In particular, the researchers found that the DNA folded into i-motifs at higher rates during a specific stage of transcription – the process that kicks off the translation of genes into proteins – when the DNA was just beginning to actively transcribe. Later, the DNA unfolded back into its usual form, and the i-motifs disappeared. According to Dinger, this probably means the i-motifs play a very specific role in regulating the transcription process.



The i-motif DNA structure. (Credit: Garvan Institute of Medical Research)

But despite knowing some of the regions in which these folds can appear, the researchers don't yet know which genes the folds control or what happens when you disturb the cell so that it cannot form these structures. Needless to say, there are years' or even decades' worth of follow-up research in store to learn more about what i-motifs are, how they work, why they exist, and how we might be able to harness their powers.